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THESIS

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AN ANALYSIS OF BUILDING A SUBMARINE BASE IN THE ARCTIC

by

Truman J. Best

March 1988

Thesis Co-Advisors: R. N. Forrest
D. C. Boger

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This thesis is an analysis of building a submarine base in the Arctic. The analysis addresses the value of a submarine base in the Arctic in relation to the growing Soviet threat in that region and the feasibility of constructing and operating such a submarine base. Location, command and control, force operation, logistic support and appropriate force size are elements of the analysis. Also included in the thesis is the cost effectiveness of the Arctic submarine base both in peacetime and in wartime situations. Based upon this limited analysis, such a base appears to be only marginally cost-effective in peacetime but substantially so in wartime.

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An Analysis of Building a Submarine Base in the Arctic

by

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Lieutenant, United States Navy
B.S., United States Naval Academy, 1981

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

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ABSTRACT

This thesis addresses the feasibility of constructing and operating a U.S. submarine base in the Arctic. Location, command and control, force operation, logistic support and appropriate force size are elements that are considered. Included in the thesis is a limited cost effectiveness analysis which suggests that such a base would not be cost effective for peacetime activities but would likely be cost effective in a conflict with the Soviet Union.

I. INTRODUCTION

A Soviet SSBN or SSGN in the Beaufort Sea is within 2400 nautical miles of Omaha, Nebraska. The U.S. has conducted ASW operations in the Beaufort Sea; however, Soviet submarines operating in that region are a potential threat to the U.S. Although technology for various submarine detecting and tracking systems moves forward, SSNs are a necessary component of Arctic ASW due to their under ice capabilities. As seen in Figure 1, no Western nation has a submarine base in the Arctic region, while the Soviets have two submarine bases there. These factors alone suggest that a U.S. submarine base in the Arctic should be considered.

Factors which should be considered in the evaluation of an Arctic submarine base are location, command and control, force operations, force size and logistics support. These will be analyzed, both qualitatively and quantitatively, in the following chapters.

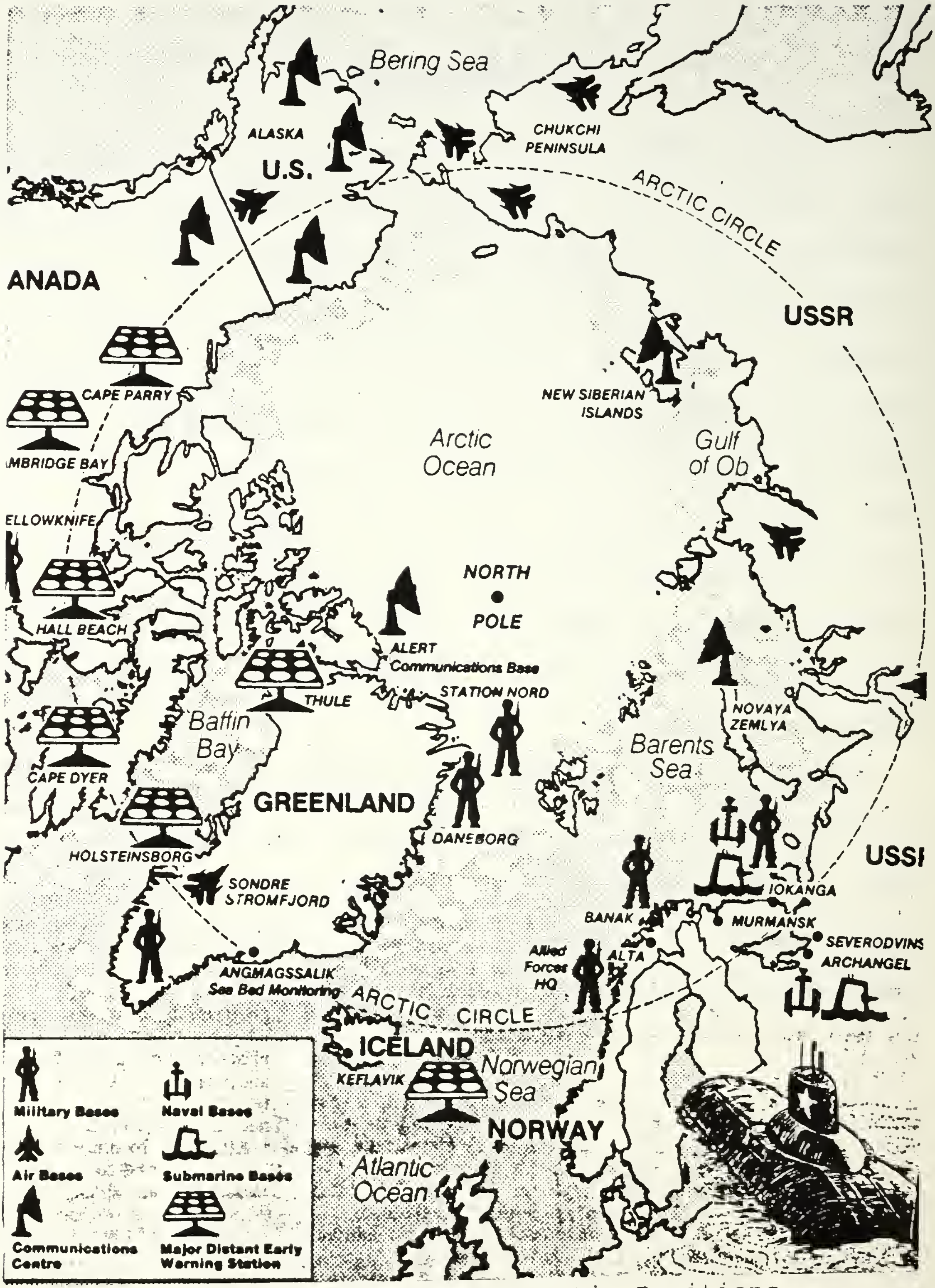

Figure 1. Strategic Arctic Positions

II. ARCTIC SUBMARINE BASE OPERATIONS

A. BASE CONSTRUCTION AND LOCATION

A U.S. submarine base on the north slope of Alaska could be built using conventional port building concepts. The Scandinavian countries, Norway, Sweden, and Denmark, along with the Soviet Union have already built many ports in Arctic regions using conventional techniques. However, they are limited in usage due to extremely cold weather during winter. Also, yearly port operation and maintenance costs are very high, in part because of ice forces exerted on structures that can result in extensive damage.

A possible location for a U.S. submarine base on the north slope is at Barrow, Alaska, since it is an established town and the area has been well researched by Arctic scientists. In addition, there is an air strip at Barrow which could be used to fly supplies to the base for logistics support. A temperate climate could be achieved by placing a dome over the submarine base. A portion of the dome could be made of a clear skin of reinforced plastics, and the base could be heated and powered by natural gas which is present in abundance on the north slope of Alaska.

In July, 1958, USS Nautilus found a submerged sea valley in the Pt. Barrow area that presented a deep water passage beneath the polar pack. Thus, when a submarine leaving the base reaches this valley, it can safely submerge and transit to operating areas via the Chukchi Sea or the Beaufort Sea. On the other hand, the Pt. Barrow shore is very shallow, being typically only two-thirds of a meter as far as four miles off shore. This presents a high cost in dredging the harbor channel.

B. COMMAND AND CONTROL

In order to operate a submarine base, some sort of command and control system must be created. As noted in Ref. 1, the U.S. needs a high level Navy advocate for Arctic theater of operations. The advocate envisioned, Commander Submarine Forces Arctic (ComSubForArctic) would be responsible to Commander-in-Chief Pacific Fleet. This command, headed by a flag officer, would be the focus for all submarine and intelligence operations in the Arctic theater.

Although submarine operations are the reason for establishing ComSubForArctic, Arctic operations involving SEAL teams and the Marine Corps could also be placed under the command. Those responsible for Arctic operations must compete for attention within their own commands in order to have any influence in the highly specific Arctic warfare arena. To affect policy, these officers must influence decisions impinging on Arctic operations in a setting where their superiors are concerned with operations in a much larger, more general arena. A more effective solution would be to assemble each representative of the scattered Arctic communities on the ComSubForArctic staff where they could directly influence the Commander. ComSubForArctic assisted by SEAL team and Marine Corps personnel could develop plans, institute and conduct exercises, assist in collecting, analyzing, and disseminating intelligence, and facilitate logistics in an appropriate manner as directed by higher authority to ensure that Navy and national interests in the Arctic theater were best served.

C. ARCTIC SUBMARINE FORCE OPERATION.

The present U.S. concept of Arctic SSN operations is to allocate Arctic periods for SSNs deploying from the West Coast or the East Coast as part of their deployment schedule. There are no submarines specifically designated for Arctic SSN operations.

The proposed concept of Arctic operation is similar to the present U.S. SSBN operations in that there would be rotating crews for the submarine force. For example, three crews might be assigned to two submarines. Each SSN would make a five month deployment and would have a two month inport period for minor repairs and proper turnover to the rotating crew, then the SSN would go out for another five month deployment. Each deployment would consist of two months in an operating area, then one month of training and readiness exercises, visits to foreign ports, possibly in Norway or Scotland for liberty, and finally a return to the operating area for an additional two months.

With this concept, a submarine would be present in the Arctic Ocean 16 months out of 26 months of operation, at the end of which it would enter drydock for four months for repairs and overhaul. It would then restart the rotation. Thus, for a 30 months cycle, a submarine would spend 16 months in the Arctic Ocean. This would meet the Chief of Naval Operations' requirement that personnel spend less than 50% of their time away from their home port, while maintaining a significant presence in the Arctic. Also, with this concept, submarines operating in the Arctic Ocean should be more effective since crews would become more familiar with the Arctic environment.

D. LOGISTICS SUPPORT

The next consideraion is to determine the operational requirement of the base. For instance, what type of support facilities should the base contain? In order to be an effective operating base, it should have the capability to support all minor repairs and some major repairs on SSNs. Although it should not be necessary to build a base with complete overhaul capability, a base should have an intermediate maintenance activity support level. The base could maintain one dry dock for extensive periodic maintenance between overhauls. For example, to repair damaged screws and sonar domes, since the probability of screw and sonar dome damage would be greater under the ice than in the open ocean as a result of surfacing and moving through ice.

Since the Arctic submarine force would conduct all Arctic operations, personnel could be made available from the other U.S. submarine bases that currently support Arctic operations. However, personnel assignments to the Arctic base could be a major problem, especially to the married person. Not many families would choose to live in the Arctic. However, if proper provisions were made for a comfortable family life, an Arctic assignment might be quite acceptable.

One way this might be accomplished is by constructing an adjacent dome that contains apartments for both married and single people, schools for children through high school, a navy exchange and commissary, and some recreational facilities.

Many of the necessities for life and proper operation of the base could be flown into the Barrow air strip. From there, helicopters or trucks could be used for transport to the submarine base.

III. ARTIC SUBMARINE FORCE SIZE ANALYSIS

This thesis is based on the assumptions that the primary objective of the Arctic Submarine Force is to neutralize the threat of the Soviet SSBN and SSGN forces of the Soviet Northern Fleet in the event of an armed conflict with the Soviet Union. This means that a U.S. submarine base in the Arctic should be large enough to support a submarine force sufficient to counter the Northern Fleet SSBN and SSGN forces. This thesis will concentrate on the SSBN forces.

As of 1986, the northern SSBN fleet consisted of four Typhoons and 11 Delta III/IV [Ref. 1]. Also, the Soviets are building one Typhoon class and one Delta IV class SSBN per year [Ref. 2]. If this rate continues, by 1995, the Soviets will have seven more Typhoons and Delta IVs. Assuming the present force allocation of 65% of SSBNs to the Northern Fleet, by 1995 the Northern Fleet might have as many as 9 Typhoons and 16 Delta III/IVs.

Two simple force size analyses are presented next. Both analyses are based on the assumption that there will be no change in force requirements in other areas of world. The first analysis is the more conservative one.

A. THE FIRST FORCE SIZE ANALYSIS

Due to Soviet advances in submarine quieting, acoustic sensors, and weapons, U.S. submarines may no longer enjoy the degree of superiority that they have had over their Soviet counterparts in the 1960s and the 1970s. This analysis is used to calculate the force size for a worst case condition in which the capabilities of Soviet SSBNs approach that of U.S. SSNs.

ASSUMPTIONS

1. The U.S. will deploy as many SSNs as the Soviets deploy SSBNs.
2. The Soviets will have 25% of their SSBNs in station at all times.
3. Without a submarine base in the Arctic, the U.S. Arctic submarine forces will use a six months deployment cycle, six months deployed, six months inport.
4. By 1995, the Northern Fleet will have 25 deployable SSBNs.

Thus, at any one time there would be seven SSBNs, (.25 * 25 = 6.25 = 7 SSBNs), deployed under the ice. Therefore, the U.S. would need to maintain seven SSNs in the Arctic. Given that it takes 15 days (this is discussed in a later section), for a U.S. SSN to transit to the Arctic from its nearest SSN base, an SSN would operate in the Arctic five months out of a year. Then, in order to maintain seven SSNs continously, which equates to 7 * 12 = 84 submarine months per year, an Arctic submarine force needs 84 / 5 = 16.8 = 17 submarines. However, with a submarine base in the Arctic and the Arctic submarine force operation concept, the U.S. submarine force size requirement would be decreased as will be seen in the next section.

B. THE SECOND FORCE SIZE ANALYSIS

This analysis is based on a random search model. The model represents a theoretical search in which the least information is known about a target and no systematic search plan is used [Ref. 3]. Thus, the force size calculated based on this method is also conservative.

ASSUMPTIONS.

1. Without the submarine base in the Arctic, U.S. forces will use a 6 months deployment cycle.
2. The total area of the Arctic Ocean is 3.3 million square miles; however, the area is subdivided into individual SSBN operating areas of equal size.
3. U.S. submarines' search efforts are independent.
4. The best search speed for an SSN is 15 kts.
5. The "cookie cutter" sweep width of a U.S. SSN sonar against a Soviet SSBN is 12 NM.
6. An equal number of SSNs is deployed to each SSBN operating area.

7. The U.S. requires probability P of at least one detection for each deployed Soviet SSBNs in a 60 day period.

The model can be stated as follows:

$$P = 1 - \mathrm{EXP}(-WL(N/n) / (A/n))$$

where

W = sweep width.

L = total distance searched by a SSN.

A = total area of the Arctic Ocean.

N = the number of submarines needed.

n = number of deployed Soviet SSBNs.

or $P = 1 - \mathrm{EXP}[-WLN / A]$ [Ref.3]

and $N = -(A/WL) * \ln(P)$

Thus, N is independent of n for this model and the number of SSNs required is the same whether the Soviets deploy one SSBN or ten SSBNs.

Example : Assume 1 SSBN is deployed and $P = .5$

Then $A = 2.557$ mil. sq. nm, since 1 nm = 1.136 miles,

3.3 mil.sq. miles = 2.557 mil. sq. nm

$L = 60$ days * 24 hrs/day * 15 kts = 21600 nm

and $N = .693 * A / W*L$

$= .693 * 2557000 / (12 * 21600)$

$= 6.84 = 7$ submarines are needed.

Therefore, the Arctic submarine force size without the Arctic submarine base must provide, 7 * 12 = 84 submarine months and this requires, 84 submarine months / 5 months =

16.8 = 17 SSNs.

Question: If P = .8 or P = .3, what is the force size?

For P = .8, N = 1.61 * 2557000 / 12 (21600)

= 15.8 = 16 submarines.

Then, the force size must provide, 16 * 12 = 192 submarine months and this requires, 192 / 5 = 38.4 = 39 SSNs.

For P = .3, N = .357 * 2557000 / 12 (21600)

= 3.5 = 4 submarines.

Then, the force size must provide, 4 * 12 = 48 submarine months and this requires, 48 / 5 = 9.6 = 10 SSNs.

The remainder of the thesis is based on the first force size analysis, since it is sensitive to the number of SSBNs deployed, and the analysis is based on Soviets' deploying seven SSBNs in peacetime and ten SSBNs in wartime.

C. WARTIME LOSSES

The probability that a U.S. SSN will be lost while transiting through Soviet SSN barriers and mine fields at choke points to the Arctic Ocean is assumed to be .2 per transit. Given a patrol force of ten SSNs and a five-month patrol period, 24 transits per year will be required, and this will result in an expected loss of 24 * .2 = 4.8 or 5

SSNs per year. This number will be used in a later analysis.

The number of the U.S. SSNs lost under the conditions considered might vary significantly depending on actual Soviet capabilities; however, with the above assumptions, the U.S. will lose on the order of five submarines per year from the Soviet barriers to the Arctic Ocean.

IV. COST ANALYSIS

A. ARCTIC SUBMARINE BASE EFFECTIVENESS

Is building a submarine base in the Arctic cost effective? The cost effectiveness analysis of the Arctic submarine base will be based on the approximate cost of building and operating the submarine base versus the number of submarines saved by operating from the Arctic base. The analysis considers two situations in the year 1995, a peacetime situation and wartime situation.

1. Peacetime Analysis

ASSUMPTION: In 1995, the Soviets deploy seven SSBNs in the Arctic Ocean.

Then from calculations in the previous chapter, the U.S. would need to maintain seven SSNs to counter the SSBN threat. Without the base in the Arctic, the U.S. needs 17 submarines to maintain continuous presence of seven submarines, but with the base only 14 submarines are required. (With the Arctic submarine force operation, a submarine operates in the Arctic Ocean 16 months out of a 30 month cycle. Since maintaining seven submarines continously requires 7 * 30 = 210 submarine-months per cycle, 210 / 16 = 13.125 = 14 submarines are needed.).

This equates to a savings of three submarines.

Question: What is the submarine savings if the Soviets deployed four SSBNs?

Then, from the first force size analysis, the U.S. would need to maintain four SSNs to counter the threat. Without the base in the Arctic, the U.S. needs ten submarines, but with the base only eight submarines are required, since maintaining four submarines continuously require 4 * 31 = 124 submarine-months per cycle, 124 / 16 = 7.75 = 8 submarines. This equates to a savings of two submarines.

2. Wartime Analysis

ASSUMPTIONS:

a. The Soviets deploy ten SSBNs.

b. The conflict lasts for one year.

c. Without an Arctic submarine base, the U.S. Arctic submarine force uses deployment cycle of five months operation in the Arctic, resupply for one month at the home port and operate for another five months.

The nearest U.S. attack submarine base to the Arctic is Groton, Connecticut, which is approximately 4300 NM to the Arctic submarine operating area. Transiting at average speed of 12 kts, it would take a submarine on the order of 15 days to reach its operating area. Thus, in a five-month operating period, an SSN would be on station for only four months and a submarine will be in the Arctic eight months per year. Then, in order to maintain ten submarines continuously for one year, which equates to 12 months * 10 submarines = 120 submarine-months, the U.S. would need 120 submarine-months / 8 months = 15 submarines. In addition, five more submarines are needed to account for the wartime loses as calculated in the previous section. Thus, the U.S. would need a total of 20 SSNs.

On the other hand, with the Arctic submarine base operation concept, a submarine could spend five months on deployment, come back to the base, allow one month to resupply and exchange the crew and deploy again for five months. In this case, the submarine would spend ten months out of a year under the ice. With this concept, only 12 submarines are needed to maintain ten submarines in the Arctic area continuously. Thus, the submarine savings are eight submarines in wartime situations

B. COST EFFECTIVENESS

1. Cost Savings Accruing From Submarines Saved

ASSUMPTIONS:

a. In 1995, the average cost of a modified Los Angeles class submarines cost 800 million dollars each.

b. Annual operating and maintenance cost of an SSN is ten percent of the procurement cost.

c. Discount rate (r) is ten percent for all years.

d. The size of Arctic submarine base is four times as large as the Astrodome.

e. A multiplication factor of 1.5 to 2.5 in cost is used to account for the Arctic weather and the transportation of building materials.

f. The average inflation rate between 1965 to 1995 is 6.5%.

g. Operation and maintenance cost of the U.S. submarine force is 25% of the total U.S. Navy's operation and maintenance cost.

h. The useful life of a submarine is 30 years.

a. Peacetime Analysis.

From the previous section, the number of submarines saved in peace time was three when the Soviets deployed seven SSBNs; thus, this equates to a savings of 2.4 billion dollars in 1995. Since Los Angeles class SSNs are built four per year, discounting is not used. In addition, the annual operating and maintenance cost discounted to 1995 dollars is calculated using the present value formula [Ref.5].

(1) PV = SUM (Ai / (1 + r)**i) i = 1 ... n

where

PV = present value.

Ai = cost at year i.

r = discount rate.

n = total number of years.

Using the above formula, with the constant discount rate of 10% and Ai = 2.4 billion * .1 = 240 million dollars for all 30 years, the operation and maintenance cost is approximately 2.3 billion 1995 dollars. Thus, the total savings from the Arctic submarine base is 4.7 billion dollars. Therefore, if the submarine base construction and operation costs are less than 4.7 billion in 1995, it could be cost effective.

If the Soviets deploy only four SSBNs, then the submarine savings is two submarines, which equates to a savings of 1.6 billion dollars in 1995. Also, using equation (1), the operating and maintenance cost is approximately 1.5 billion 1995 dollars. Thus, the total savings from the Arctic submarine base is 3.1 billion dollars.

b. Wartime Analysis.

The submarine savings from the Arctic base operation in wartime, from the previous analysis, was three submarines. Also, there are approximately five submarines lost per year from Soviet SSN barriers and the mine fields at the Arctic choke points. Thus, the total submarines saved might be eight submarines for a one year campaign. This equates to savings of approximately 12.6 billion 1995 dollars.

2. Cost Expenditures for the Base

a. Investment Costs

Since there are no facilities that are equivalent to an indoor submarine base, a rough approximation of the investment cost will be derived using a formula that gives an order of magnitude cost estimate and the cost of the Astrodome in Houston, Texas as the base case [Ref. 4].

A formula which can be used for scaling up or down structure costs is:

$$Cx = Ck * (Ex / Ek)^{**}n$$

where

Cx = cost of item of size Ex

Ck = cost of item of size Ek

n = cost capacity exponent (= .85 [Ref .4])

The Astrodome in Houston, Texas, built in 1965, cost $31.6 million dollars. Its overall size is 216 meters by 216 meters, the outside wall is 66 meters high, and the diameter of the dome is 196 meters. Assume an Arctic submarine base with proper facilities to support 14 submarines can be built on a lot size of 432m by 432m, have a height of 66m and a dome diameter of 400m. This facility then would be four times as large as the Astrodome.

From the above formula, the investment cost of the Arctic submarine base in 1965 dollars is 102.7 million:

$$Cx = 31{,}600{,}000 * (4)^{**}.85 = 102.7 \text{ Mil.}$$

Since construction cost in the Arctic is not comparable with that in a temperate climate, and to account for the large transportation cost for the building materials, a multiplication factor of 1.5 to 2.5 is used for the Arctic submarine base construction. Using these factors, the cost would be about 102.7 mil * 1.5 = 154.05 mil. to 102.7 mil * 2.5 = 256.75 million in 1965 dollars for the base.

Assuming the Astrodome would be large enough for the living quarters then, an additional 31.6 mil * 1.5 = 47.4 to 31.6 mil * 2.5 = 79 million dollars would be required. So, the total investment cost for the Arctic submarine base might be 201.5 to 335.75 million in 1965 dollars.

The $335.75 million in 1965 dollars can be converted to 1995 dollars by adjusting for inflation. The average inflation over the 30 years is assumed to be about 6.5% [Ref. 5]. Then,

```
C[in 95] = C[in 65] * (1 + .065)**n
```

where

C[in 95] = cost in 1995

C[in 65] = cost in 1965

n = number of years

Using this formula, 335.75 million in 1965 is equvalent to 2.22 billion in 1995. Likewise, 201.5 million is equivalent to 1.33 billion in 1995. The estimated accuracy of the "order of magnitude estimate" is -30%,+50% [Ref. 4]. Thus, the cost might range between .9 billion to 3.33 billion 1995 dollars.

In addition, although the Astrodome has some buildings included, extra building facilities would be needed for the submarine base operations. Adding an extra investment cost of .5 billion in 1995 dollars to account for this, the total investment cost of the base might range between 1.4 to 3.83 billion 1995 dollars.

If the Soviets deployed only four SSBNs in peace time, the Arctic submarine force size need to be only eight SSNs. However, in wartime the Soviets would most likely increase the number of SSBNs deployed. Therefore, the submarine base size will still be the same, which implies that the investment cost of the submarine base might range from 1.4 to 3.83 billion 1995 dollars.

b. Operation and Maintenance Costs

The operational cost of the proposed Arctic submarine base is calculated using the 1987 Navy budget request, which was 94 billion dollars. Ten percent of 94 billion was for the operation and maintenance of all U.S. Navy support facilities [Ref. 2]. Since the submarine force comprise approximately 25 percent of the U.S. Navy, 25 percent of the total operations and maintenance cost will be spent on submarine base operations. The U.S. submarine force size is about 130 submarines, so the operation and maintenance cost of a submarine base with 14 submarines might be approximately one-tenth of the total submarine base operation costs. Then, the operation and maintenance cost of the Arctic submarine base might be (for 30 years), again using formula (1), approximately 2.24 billion in 1987 dollars; if the Arctic factor of 1.5 to 2.5 is considered, then, the cost would range between 3.36 billion to 5.6 billion in 1987 dollars. This is equivalent to about 5.56 to 9.27 billion in 1995 dollars, again using a constant 6.5% annual inflation rate.

In addition, there would be varying costs of channel and harbor dredging, ice breaking and defense systems for the submarine base. These costs might range from one to three billion 1995 dollars, based on the dredging costs, the amount of ice breaking needed and the defense system costs. Thus, the total cost of the Arctic submarine base might range from approximately eight to 16 billion dollars.

If the Soviets deploy four SSBNs, the Arctic submarine force size is eight SSNs. Then, the operation and maintenance cost would range between 3.2 to 5.3 billion 1995 dollars. The cost of dredging, ice breaking, and defense systems would still remain about the same one to three billion 1995 dollars. Thus, the total cost of the submarine base might range 5.6 to 12.2 billion 1995 dollars.

C. SUMMARY

Table 1 indicates that the Arctic submarine base is not cost-effective in peacetime but likely be cost effective in wartime.

Table 1

COST SAVINGS AND EXPENDITURES (1995 DOLLARS)

	Peacetime(4)	Peacetime(7)	Wartime(10)
cost savings	3.1 bil.	4.7 bil.	12.6 bil.
investment cost	1.4 to 3.8 billion		
O & M cost	4.2 - 8.3 bil.	6.6 - 12.3 bil.	
cost expenditure	5.6 - 12.1 bil.	8.0 - 16.1 bil.	

* The number in parenthesis indicates the number of SSBNs deployed.

V. CONCLUSIONS AND RECOMMENDATIONS

The cost analysis of the thesis indicates that an Arctic submarine base is likely to be not cost effective during peace time, 4.7 billion cost savings versus 8.0 to 16.1 billion cost expenditure; however, it would likely be cost effective in war time, in which case the cost savings are 12.6 billion. In any case, the decision to build a submarine base in the Arctic should not be based on cost alone.

The other benefit of having a submarine base might be more effective ASW in that region, since the crew would be familiar with the environment. Also, the Los Angeles class submarines equipped with land attack Tomahawk missiles just outside of the Soviet territory might be a significant strategic deterrent against the Soviets.

On the other hand, the Soviets might consider the U.S. Arctic submarine base as a threat to their national security; consequently, they might build up their Arctic submarine force even larger. That might start a strategic arms race in the Arctic.

In a report by former Secretary of the Navy, John Lehman, it is stated, "For purpose of deterrence, crisis management, and diplomacy, we must be present in the areas where we would have to fight if war broke out."[Ref. 2] This suggests that the U.S. needs to increase its presence in the Arctic. An Arctic submarine base is one option for increasing the U.S. presence there. The cost analysis of this thesis is very rough. It might be within a factor of two to three of the real costs. However, it provides a starting point for an in-depth analysis of the cost effectiveness of building a submarine base in the Arctic.

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